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USE OF REMOTE SENSING FOR LAND USE POLICY FORMULATION

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Introduction

This has been an exciting year for the Center with many significant accomplishments. Also, with the evolution of the new global habitability programs, particularly the land-related sciences efforts, we have found that many of our existing programs fit well into this new proposed thrust area of NASA. In addition, preliminary analysis of thematic mapper data shows that it will open broad new horizons in providing informational content that could not before be obtained from available remotely sensed data.

Because of the diversity of the Center's activities and the wide number of participating scientists, our research and technology transfer efforts involve a number of subject matter areas. As renewable resources become increasingly important, the need for identifying forest types becomes extremely important. The study by Carl Ramm and Denny Hudson examined this area with the use of Landsat data. Their overall accuracy for forest cover type identification was 85%. Thus, these and future techniques will be extremely useful to many industries. Further research efforts will study forest vegetation identification as it relates to biomass, deforestation and NCO_2 flux studies.

Energy balance and hydrologic cycles require knowledge of synoptic temperature patterns. Extensive analysis showed that HCMM data can provide this type of information and it appears that GOES data would also provide valuable information on a diurnal basis. Preliminary indications are that this information will help with the understanding of man's impact on the surface conditions of this planet and the data can be used in models to aid in determining energy balance and hydrologic studies.

As man's activities (with increasing population demands throughout the world) are impacting land cover and land use, it is increasingly important that

we can develop techniques for detecting change and updating inventories of surface conditions. The project entitled Land Surface Change Detection outlines significant progress in this general and important area. This analysis has already shown classification accuracies for the urban and forestry test sites approaching the 75% accuracy standard used in the preliminary study. A much better understanding is evolving relative to the relationship with the diversity and spatial complexity of the test sites being classified. The preliminary thematic mapper data available shows that significant increases in accuracy will be possible with this information.

Soil mapping is one of the major undertakings in inventorying our key resources worldwide. The study on "Determination of Soil Map Unit Composition by Electronic Scanning Densitometry" examined new methods for aiding in soil map unit composition determinations and outlines the accuracy that can be expected.

The research dealing with virus infection of vineyards and blueberry fields is an important basic study. Plant diseases have a major impact on crop productivity and fundamental studies are required, such as this one, to better delineate the value of remote sensing, its limitations and research directions for improving sensor capabilities.

Several contractual activities were done under the broad responsibilities of the Center for Remote Sensing. These included an Important Farmlands Inventory for several Michigan counties which identified areas of prime and unique farmlands. Another project studied changes in the aquatic vegetation in Saginaw Bay and showed how remote sensing could be a key tool in delineating over time the extreme variations that occurred in aquatic vegetation areas. The study used historic aerial photography and the capabilities of a geographic information system to analyze a 28-year time sequence of changes in the amount and distribution of aquatic vegetation. The analysis showed clearly that dramatic

shifts do occur and it provided aerial statistics and documented some of the cyclic patterns involved. A special study was undertaken using aerial photography in hybrid poplar research. The hybrid poplar research program is particularly significant as we look to the future when bioenergy plantations will become increasingly important. These efforts are helping to develop techniques for inventorying the bio-resources available through hybrid poplar plantations.

Close ties have evolved with an international project in the Department of Resuorce Development at MSU which is titled Comprehensive Resource Inventory and Evaluation System (CRIES). Major resource inventory projects are on-going in Jamaica, Honduras, Dominican Republic and Kenya. This project provides support to the Center for certain CRIES-related activities, which have many implications for the global habitability program from an international standpoint. Through the CRIES project new detailed data bases have been developed for several countries and cross-checked with ground truth information. Our past international work could provide key sites for many studies on changes in cropping practices, deforestation, and in the broad areas of biological productivity and impacts on the hydrological cycle.

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RESEARCH PROJECTS

IDENTIFICATION OF CONIFEROUS FOREST TYPES IN MICHIGAN

USING LANDSAT IMAGERY

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This study evaluated the use of Landsat computer enhanced imagery for mapping coniferous forest types in Michigan's northern Lower Peninsula. Visual interpretation procedures were developed and tested over two sites to determine the feasibility of identifying coniferous species. The accuracy achieved by two interpreters was compared and summarized in contingency tables. Overall classification accuracies were 85 and 73 percent whereas individual species interpretability accuracies ranged from a low of 32 percent for mixed pine stands to 95 percent for jack pine plantations. Most of the errors in mapping the pines were accounted for by confusion between the individual pine species. The swamp conifer type had consistently low interpretation accuracies at both test sites. Other factors affecting interpretation accuracies were also identified and are reported.

The objective of this study was to evaluate the accuracy of mapping coniferous forest types in the northern Lower Peninsula of Michigan through visual interpretation of computer-enhanced Landsat imagery.

The climate, physiography and soils of the northern Lower Peninsula combine to create a unique habitat region, as compared to the southern Lower Peninsula or the Upper Peninsula. One of the most distinctive landscapes are high outwash plains near the center part of the region, which are dominated by stands of pines and oaks. These extensive, flat, sandy plains, which formerly supported the large white pine forests of Michigan, support much of the nearly seven mil-

lion acres of forest found in this unit.

Hardwood forests are more extensive than the softwoods with aspen-birch, a sub-climax type, the most common throughout the region. The northern hardwood type is most prevalent in the northwestern counties, while lowland hardwoods are primarily restricted to riparian sites. The softwoods, or coniferous forest types, occupy approximately 22 percent of the region. Three-fifths of these conifers are pines; jack pine, the most important pine sub-type, accounts for more than half the acreage. Jack pine occurs as a relatively pure type in a broad belt from the central northeastern area, south and west to the southwest central area. Significant areas are also found in the east and westcentral counties. The swamp conifer types, consisting predominately of cedar with lesser areas of black spruce, balsam fir-white spruce and tamarack, comprise under 9 percent of the forest land. These swamp conifers occur most frequently as small patches of a few acres on wet lands. The exceptions are in the northeastern counties where these species are more frequent and exist as larger stands.

Two test sites were chosen in the northern Lower Peninsula to be representative of areas now supporting large acreages of conifers. The first test site was located in west central Wexford County (T. 22 and 23 N., R. 12 W.) and is underlain primarily by stratified sand and gravel outwash deposits confined to a broad valley (i.e., a valley train). Most of the area was cleared for agriculture at one time, but later was abandoned as unsuitable for sustained crop production. The present forest covers over 40 percent of the area and is predominately pine plantations. Red pine accounts for 60 percent of the plantations, jack pine is predominate in 29 percent of the plantations and 11 percent are mixtures of red and jack pine. Ten percent of the forest land is composed of the swamp conifer type. These stands, composed of scattered northern white-

cedar intermixed with lowland hardwoods, are concentrated along several creeks traversing the region. The second test site was located in northeastern Crawford County and Southeastern Otsego County (T. 28 and 29 N., R. 1 W.). This area is part of an extensive outwash plain and is typical of the "jack pine flats" of the northern Lower Peninsula of Michigan. No evidence of land clearing for agriculture is present and the forest is entirely natural (e.g. there are no plantations). The area is nearly entirely forested, with conifers dominant on 72 percent of the area, the remainder being predominately hardwoods, grass or brush. Pines are located throughout the site except for two large swamps which support lowland conifer species. Jack pine is by far the predominant species throughout the site and represents over 70 percent of the softwood acreage.

Since the study dealt only with coniferous vegetation, a "leaf-off" scene was chosen because of its sharp tonal (color) contrasts of several coniferous forest types. Based upon an initial analysis of this scene and the characteristics of the coniferous forest distribution in the northern Lower Peninsula, a classification scheme was developed.

Because of their large aggregate acreage and wide distribution, stands of jack pine, red pine and mixed stands were delineated but white pine, which represents less than 1 percent of the forest land, was not separated out. Lowland conifers, because of their small total acreage and tendency to form highly mixed stands, were grouped into a single category.

To facilitate interpretation and mapping functions, a pin-registered overlay system was utilized. For each test site a base map was constructed from U.S. Geological Survey topographic maps. These maps, at a scale of approximately one inch to the mile, were registered, via punched holes aligned by a metal pin bar, with the "ground truth" maps and the Landsat interpretation maps.

This system permitted precise overlaying and comparison of two or more of the separate maps.

Prior to actual photo-interpretation, the two interpreters were given preliminary training, including the development of photo-interpretation training aids. Photo keys were prepared to illustrate the appearance of the different coniferous forest types on Landsat false-color composites. Additional training consisted of the systematic comparison of several examples of each forest type on high-altitude color infrared photography and on the Landsat color composite, coupled with specifically gathered forest stand inventory measurements.

The interpretation entailed the enlargement of the Landsat color composite on a precision rear projector. Magnification was controlled by matching the enlarged Landsat scene to the previously-prepared base map, and then replacing the base map with a blank sheet of polyester film. Utilizing the previous photo comparisons and photo keys, the interpreters identified and delineated the boundaries of all coniferous forest stands. Tone, and, in some cases, texture, were the main interpretation criteria for the pine classes. Proximity to stream courses and water bodies were an additional aid in distinguishing between upland pine types and lowland swamp conifers.

To evaluate the accuracy of the visual interpretation procedure, the Landsat interpretations were compared with previously compiled cover type maps. These maps, which were prepared specifically for this project, were constructed from photo-interpretation of medium-scale (1:24,000) color infrared photography. Additionally, both U.S.D.A. Forest Service and Michigan Department of Natural Resources forest cover type maps were consulted in conjunction with ground verification by field crews.

All errors in each Landsat interpretation map were identified by superimposing these maps on the cover type maps using the pin-registration system. The

area of each stand was measured using a 160 dot/inch^2 grid and the results summarized in contingency tables (Tables 1 and 2).

Table 1. Landsat Classification Performance, Wexford County Test Site.

Known Cover Type	Number of Sample Points Classified as--[1] Red Pine	Jack Pine	Pine Mixtures	Swamp Conifers	Non-Forest	Cover Type Total
Red pine	774	8	130	26	103	1,041
Jack pine	31	391	17	10	48	497
Pine mixtures	71	7	87	9	13	187
Swamp conifers	16	2	0	143	36	197
Non-forest	57	3	36	89	2,590	2,775
Total	949	411	270	277	2,790	4,697
Percent correct[2]	82	95	32	52	93	85[3]

[1]Values along the diagonal represent correctly delineated and identified cover types.

[2]Ratio of diagonal value to the total count of that cover type as interpreted from the Landsat scene.

[3]Overall classification accuracy; ratio of the sum of diagonal values to the total number of sample points.

These two-way cross-tabulations permit the results to be viewed from two approaches. By reading across a row one may observe which categories, and to what degree of accuracy, a particular cover type was delineated. By reading down a column, one may observe the actual cover types composing each Landsat classification. For discussion purposes, accuracy was summarized as the ratio

(expressed as a percent) of correctly delineated and classified stands to the total count of that cover type as interpreted from the Landsat scene.

Table 2. Landsat Classification Performance, Crawford County Test Site.

Known Cover Type	Number of Sample Points Classified as--[1] Red Pine	Jack Pine	Pine Mixtures	Swamp Conifers	Non-Forest	Cover Type Total
Red pine	23	38	0	1	16	78
Jack pine	9	1,500	18	18	33	1,578
Pine mixtures	0	23	33	11	10	77
Swamp conifers	0	125	1	398	19	543
Non-forest	2	301	1	222	07	833
Total	34	1,987	53	650	385	3,109
Percent correct[2]	68	75	62	61	80	73[3]

[1]Values along the diagonal represent correctly delineated and identified cover types.

[2]Ratio of diagonal value to the total count of that cover type as interpreted from the Landsat scene.

[3]Overall classification accuracy; ratio of the sum of diagonal values to the total number of sample points.

Table 1 summarizes the Landsat interpretation accuracies for the Wexford County test site, which had an overall classification accuracy of 85 percent. The high accuracies obtained for both red and jack pine are probably a direct result of their high stocking levels and frequent occurrence in pure plantations. Mixed plantations, where neither species represents more than 75 percent

of the stocking, were consistently misclassified. Further investigation revealed that two-thirds of these errors were accounted for by commission and omission errors to the red pine type. Additional cross checks confirmed that the majority of errors in the pine types were due to misclassifications among the several pine species.

Accuracies obtained without considering the within-pine variability, that is, utilizing a "pooled" pine category, show that pines were correctly interpreted 93 percent of the time.

The swamp conifer type was correctly delineated and classified with approximately 73 percent accuracy. The lower reported accuracy (52 percent) resulted from a large commission type error. Upon examining the medium-scale photography, the majority of these errors were found to occur over swamp areas dominated by lowland brush and/or lowland hardwood species. Further "lumping" of species was attempted and indicated that forest land as a single category was interpreted with 90 percent accuracy.

Table 2 summarizes the Landsat interpretation accuracies for the Crawford County test site. The lower accuracies for both red and jack pine may be caused by their lower stocking levels, with many stands grading into non-forest categories (i.e., less than 25 percent stocked). The various forest types encountered at this site exhibited less contrast than those at the Wexford County site. Most errors in the pine categories occured among the various pine types, and in recognizing hardwoods intermixed with low density pines such as jack pine. Again, "pooling" the pine types increased overall interpretation accuracy to 77 percent for the pine category.

Errors in swamp conifer type were similar to those found in the Wexford County site. Lowland brush, often with scattered trees, were the most frequently misinterpreted areas, although some confusion between jack pine and

swamp conifers did occur. The overall forest/non-forest accuracy was 81 percent. This was substantially below that obtained over the Wexford County site.

INVESTIGATION OF SYNOPTIC TEMPERATURE PATTERNS IN MICHIGAN AS DETERMINED VIA GOES AND HCMM THERMAL IMAGERY

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Considerable additional progress had been made in the use of meteorological satellite data information. Additional digital GOES data tapes have been acquired. These took a considerable length of time to obtain, however, they have now been examined, screened and are ready for detailed statistical analysis.

HCMM data has been acquired of approximately 12 scenes over Michigan, one scene over Georgia and two scenes over Florida. Preliminary analysis of this information shows that the data looks good and provides extremely valuable information on temperature patterns and reflectances as influenced by man's activities and alterations of the earth's surface.

Use of this information in more quantitative approaches has resulted in a paper (see Appendix). This paper pulls together past unpublished information by the author as well as new analysis that has been made during the last contract period. The paper summarizes the past information, our new knowledge and the implications and need for further analysis. A part of this activity led to a proposal entitled, "Temperature and Reflectance Monitored from Satellites as an Indication of Shift and Impact of Vegetation Change." This proposal will be funded out of NASA Goddard.

LAND SURFACE CHANGE DETECTION USING SATELLITE DATA AND A GEOGRAPHIC DATA BASE

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The basic objective of this research is to develop methods and techniques for the detection, monitoring and modeling of land surface changes from data acquired by satellite sensor systems. Data from the Landsat multispectral scanner (MSS), weather satellites, and the new Landsat Thematic Mapper (TM) are being evaluated to determine the capability to accurately identify land cover and land use types and detect land surface changes.

The research is being conducted in cooperation with the Michigan Resource Inventory Program, which is currently implementing a legislated statewide information system. The system includes digitized photo-derived land use information which will serve as the baseline data set for comparisons with computer-aided classifications of satellite digital images. The aim is to develop and evaluate techniques and methodologies for integrating and processing data obtained from satellite sensors with data layers in the geographic information system of the state. This research will eventually lead to the design of multi-stage change detection research.

Several research areas have been identified which will provide techniques needed as components of an overall system for monitoring land cover/use changes and updating regional and statewide geo-referenced data bases. Other areas of research are being defined related to integrating and analyzing satellite data

with selected earth surface attribute sets of the data base, particularly information on forest stand type, size and density. A summary of the current efforts in each research area follows.

IMAGE REGISTRATION

Accurate image registration is a prerequisite for most change detection and inventory update methods. We have, therefore, concentrated our initial work in this area. Techniques to handle three types of image registration will be required for the research, i.e., image to image, image to geographic data base and image with ancillary data sets such as digital elevation data.

Several multi-image registration algorithms have been developed and evaluated during this reporting period. Emphasis had been placed on automatic digital image registration procedures that handle images with translational, rotational and scaling differences. One procedure, which has been reported in a paper (see Appendix), involves 1) segmentation of images, 2) isolation of dominant objects, 3) determination of corresponding objects in the two images and 4) estimation of transformation parameters using the center of gravities of objects as control points. This method has been used to register different images of Michigan acquired by the Heat Capacity Mapping Mission (HCMM) satellite. HCMM images have also been registered with images from the Geostationary Operational Environmental Satellite (GOES) using invariant moments.

Attempts were made to register airborne thematic mapper (TM) simulation data with a Landsat MSS scene. Geometric distortions in the aircraft data prevented a good fit, however we believe that a recently-acquired Landsat TM scene can be properly registered to Landsat MSS scenes.

We have also begun to explore computer-based techniques for the determination of pixel elevation based upon the registration of stereo images. These techniques will be useful in the analysis and classification of data from

pointable sensors on satellites.

Work on the registration of digital images to the states geographic information system (GIS) data files has not been started due to problems in reformatting the GIS data for tape output. When tape reformating is accomplished, routines will be written to handle polygon-to-raster conversions and image to data base registration.

As an initial check of registration potential, a county area on a Landsat TM Band 5 scene was photographically enlarged to a scale of 1:48,000 and overlayed with a clear-acetate copy of a computer-drawn land use map from the Michigan Resource Inventory System. The information content (tonal areas) in the Landsat TM scene coincided perfectly with the polygonal areas of the land use categories shown on the map. Based on the goodness of fit of the photographic products, we believe that the corresponding digital data sets can be easily and accurately registered.

To date no work has begun on merging ancillary data sets with digital images from satellite sensors. However, digital elevation data for two 1:250,000 topographic quadrangles has been ordered and received from the National Cartographic Information Center.

IMAGE SEGMENTATION

Change detection through scene analysis of multiple digital images often requires adequate segmentation of the images. Various techniques for image segmentation will eventually be evaluated including edge operators, thresholding, region growing and multi-image segmentation procedures for determining corresponding regions in two data sets. Resultant binary masks for forest and urban features will then be employed to limit image classification and change identification within predefined areas. Preliminary research was conducted this reporting period on using image segmentation techniques to isolate road networks

in aircraft thematic mapper simulation data. Roadways are important recognition criteria in the identification of residential subdivisions which are an important land use category requiring frequent updating.

IMAGE CLASSIFICATION

The initial work in this research area is reported in a Ph.D. Dissertation entitled An Evaluation of Digital Landsat Classification Procedures for Land Use Inventory in Michigan.[1]

The major research objective of this study was to evaluate the informational value of Landsat digital data in the context of providing land use data to users in Michigan. Information on user needs was developed through an extensive survey focusing primarily on land use planners. Land categories were identified and subsequently modified in order to be compatible with processing of Landsat data.

Three test sites, each characterized by a distinct land use type (agricultural, urban and forest) were chosen to evaluate Landsat performance. For each of these sites Landsat data for August 16, 1979 were classified by means of three commonly available algorithms (maximum likelihood, minimum distance-to-means, grouping of cluster classes). Accuracy evaluation of the resulting classifications included examining the effects of generalization for geographic information system formats.

Conclusions derived from the study can be summarized in three major areas. Analysis of land use categories identified by questionnaire responses, in conjunction with limitations imposed by the characteristics of the Landsat data, show that the minimum land use requirements of the majority of planners surveyed

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1 Hill-Rowley, Richard, 1982. An Evaluation of Digital Landsat Classification Procedures for Land Use Inventory in Michigan. Ph.D. Dissertation, Department of Geography, Michigan State University, East Lansing, Michigan.

could not be fulfilled by the classification procedures. The categories that remained, nevertheless, represent the dominant land use classes in each of the areas selected. Accurate updating and/or remapping of these categories would be of considerable value.

Classification accuracies for the urban and forest test sites approached the 75% accuracy standard used in the study. Accuracies for the agricultural site were significantly lower. Variations were present among algorithms, with the unsupervised grouping of cluster classes substantially superior in the agricultural site, maximum likelihood the most accurate in the urban site and minimum distance-to-means preferable in the forest site. Despite this distribution, no significant difference existed at the 95%-confidence level between the overall performance of the algorithms.

Accuracy analysis of the generalized Landsat classes, when compared with geocoded land use types derived from airphoto interpretation, resulted in a substantially lower accuracy than the same comparison between actual aerial photography and the pixel-based Landsat classification. The extent of this accuracy loss seems to have a direct relationship with the diversity and spatial complexity of the test site being classified.

CHANGE DETECTION

No work on change detection techniques was performed with Landsat digital data this reporting period due to the previously-stated problems with the tape routines of the state's GIS system. However, preliminary evaluations are being made of the superimposed Landsat TM/GIS Landuse Map product. The landuse data was obtained from 1978 color infrared aerial photography whereas the TM data was acquired in October 1982. The most predominant changes identified through visual analysis were forest clear-cut areas and new pads for oil/gas wells. The oil/gas pads are easily identifiable on TM images because of their regular

geometry and aeral dimensions. Work is underway to automatically pin-point the geographic location (latitude and longitude) of oil/gas pads. This will require an evaluation of the relative geometric accuracy of the state's GIS data files and the Centers Landsat geometric correction routines.

DETERMINATION OF SOIL MAP UNIT COMPOSITION BY ELECTRONIC SCANNING DENSITOMETRY

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Modern soil survey reports provide information on the soil resources of an area to a wide spectrum of public and private users. Natural soil boundaries are located by soil scientists in the field and delineated on an aerial photographic base. Some map units are made up of primarily one kind of soil, while others are made up of two or more soil series. Most soil map units include small areas of other soils because the map scale and nature of the soils in the area do not permit the separation of these small areas. In some map units these included soils have properties that differ substantially form those of the dominant soil or soils and, thus, could significantly affect use and management of the map unit. A soil complex is used to represent areas where two or more soils make up a large portion of the map unit but are so intricately mixed or so small in size that they cannot be separated on the soil map.

The percent composition of each soil in a soil complex is reported in the soil survey report. These data are obtained from field observations. Statistical sampling methods and ground enumeration techniques have been developed to improve the accuracy of these map unit composition data. However, most of these methods are labor-intensive and not extensively utilized.

Many soil complexes in Michigan have a mottled appearance on aerial photography because of differences in soil moisture, organic matter content, surface texture and/or vegetative variation. Imagery of bare or sparsely vegetated ground collected during spring months generally provides the most distinctive patterns. Soil scientists recognize relationships between some tonal patterns and kinds of soil. Thus, photointerpretation is an important part of soil map-

ping. Electronic scanning densitometry can classify the range of density values into range categories and rapidly determine the percentage composition within an area.

The objective of this study is to evaluate the suitability of electronic scanning densitometry to accurately determine soil complex composition in a timely and cost-effective manner.

METHODOLOGY

Three soil complexes, Tappan-Londo loams, 0 to 2 percent slopes, Tappan-Avoca complex, 0 to 3 percent slopes and Guelph-Londo loams, 0 to 6 percent slopes, were selected for investigation. The classification of the soil series are:

Tappan - Typic Haplaquolls, fine-loamy, mixed (calcareous), mesic

Londo - Aeric Glossaqualfs, fine-loamy, mixed, mesic

Avoca - Entic Haplaquods, sandy over loamy, mixed, mesic

Guelph - Glossoboric Hapludalfs, fine-loamy, mixed, mesic

Two fields of each complex were located in Tuscola County, Michigan where a modern soil survey is in progress. Thus, the findings of this study would benefit the survey party in preparing composition estimates of these soil complexes. Each of the fields had no or sparse vegetation at the time the aerial photograph was taken.

Using black-and-white panchromatic aerial photo transparencies the six fields were digitized using an EYECOM Image Scanner (Spatial Data Systems). The cell size used was about 3 m square.

To determine the composition of the soil complexes, observations were made in a grid pattern at 30 m intervals. Soils were classified to the soil series level in the field. Surface horizon texture, type of surface horizon, depth to free carbonates, and thickness of sand, where present, were recorded for each

observation.

The soils data will be overlaid on the digitized density maps to determine the range of density values for each soil in the complex. Then the composition of the complexes will be determined using the digitized data and compared with that determined from field observations.

RESULTS

An example of the digitized soil map for the Tappan-Londo complex is shown in Figure 1. The density ranged from 0 (dark) to 255 (light). The range of density for Tappan was 50 to 100 and for Londo was 100 to 174. For the field in Figure 1 the composition is 52 percent Tappan and 48 percent Londo.

The composition of the three soil complexes based on field observation is given in Table 1. The Tappan-Londo complex is composed of about 50 percent Tappan and 40 percent Londo with 5 percent Parkhill and 4 percent other soils. Parkhill had properties similar to Tappan while the other soils were more similar to Londo. Combining these soils the composition of soils with reflectance properties similar to Tappan is 55 percent and those similar to Londo is 44 percent. These values are not significantly different from those estimated for the field in Figure 1 using electronic scanning densitometry. This indicates the potential for the use of this technique to determine composition of soil complexes.

FUTURE WORK

The comparison of the soils data with the density maps of the remaining five fields will be completed. This will give a more accurate evaluation of the use of electronic scanning densitometry to determine composition of soil complexes.

138	132	137	128	48	63	85	70	84	99	83	73	60	83	94	120	111	91	100	79	99	101
129	132	127	108	59	57	77	58	63	118	115	105	75	114	104	153	117	104	94	93	117	97
101	77	99	95	53	61	108	62	102	151	126	79	91	117	130	167	140	109	98	92	125	119
112	77	91	92	57	47	102	69	103	151	117	94	99	101	105	159	150	109	83	92	113	100
95	118	123	98	68	79	88	60	87	152	99	80	99	120	110	159	135	105	101	89	92	79
104	106	110	115	87	71	94	67	94	137	108	93	97	88	131	164	112	108	81	111	81	79
96	74	95	113	101	84	95	65	90	136	121	107	96	97	141	153	117	100	56	89	77	83
84	81	74	65	71	65	75	83	77	132	124	110	92	123	149	166	119	117	78	87	102	65
84	69	58	68	65	76	73	78	69	108	140	127	98	142	157	174	115	113	83	94	82	92
120	78	65	58	55	79	70	75	63	99	136	122	103	127	144	160	115	112	85	115	106	99
148	127	118	109	93	78	84	77	82	93	127	103	95	95	145	160	106	120	104	99	95	100
129	128	123	137	86	70	132	119	97	105	144	126	93	95	149	163	104	122	109	92	119	109
121	93	107	144	89	83	122	137	110	113	149	163	94	79	123	161	104	90	94	93	103	150
124	103	121	132	99	67	78	136	105	94	156	149	94	85	68	107	80	113	91	95	104	125
127	116	114	99	110	72	90	117	109	84	112	145	95	99	78	88	93	106	86	82	81	138
136	121	98	89	118	77	90	98	100	78	92	140	103	75	98	83	98	112	76	93	89	104
138	119	66	89	136	86	76	80	111	75	78	137	148	73	127	90	89	85	86	130	87	84
122	116	50	76	106	76	83	106	124	89	73	113	130	85	81	83	92	80	69	116	102	81

Figure 1. Digitized density map for field in section 4 of Tuscola Township, Tuscola County, Michigan.

Table 1. Composition of three soil complexes as determined from field observations.

Complex	Soil Series*	Percent
Tappan-Londo	Tappan	50
	Londo	40
	Parkhill	5
	Capac	2
	Other soils	2
Tappan-Avoca	Tappan	22
	Avoca	1
	Selfridge	48
	Wixom	2
	Capac	5
	Londo	3
	Parkhill	1
	Brookston	1
	Metamora	1
	Corunna	3
	Belleville	8
	Other soils	5
Guelph-Londo	Guelph	52
	Londo	7
	Marlette	13
	Capac	9
	Metea	6
	Owosso	3
	Metamora	1
	Selfridge	3
	Oshtemo	2
	Parkhill	1
	Other soils	3

*Other soils represents soil series which were encountered at only one observation.

DELIMITING AREAS OF VIRUS INFECTION IN VINEYARDS AND BLUEBERRY FIELDS OF SOUTHWESTERN AND WESTERN MICHIGAN

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Michigan blueberry growers have experienced considerable economic loss from the infection and spread of two serious virus diseases, blueberry shoestring virus (BBSSV) and blueberry leaf mottle virus (BBLMV). Approximately 56% of the commercial plantings are of the cultivar Jersey; one of the most susceptible varieties to both diseases.

Another virus disease on grape, peach rosette mosaic virus (PRMV), has cost growers millions of dollars. More than 50 vineyards in the southwest section of the state experience crop loss due to this disease. All three diseases are transmitted readily by insect or nematode vectors.

An increase in the number of fields becoming infected and resultant economic implications, makes early detection important. Control strategies for these diseases include rouging and replacement of bushes and vines exhibiting visual symptoms. However, a four year latent period is necessary before symptoms are expressed, while infected plants serve as inoculum reservoirs. The ELISA (Enzyme-linked Immunosorbent Assay) technique while providing an accurate procedure for detecting individual bushes, is costly and impractical on a commercial basis. Therefore, the need exists for the development of a cost-effective, accurate and rapid method to discriminate between diseased and healthy plants. One approach is the use of remote sensing to observe spectral and geometric changes in plant canopies, using photography and field spectrophotometric readings at various phenological stages. If practical, these methods would enable growers to rapidly assess the extent of infection before control

measures are initiated.

MATERIALS AND METHODS

Ground Truth

To correlate changes observed on photographic imagery or spectrophotometric readings, areas within infected blueberry fields and vineyards were selected based on a visual assessment of diseased and healthy conditions. Maps (Fig. 1) of these areas were constructed and the verification of infected plants was made using ELISA results.

Aerial Photography

Aerial photographs were taken of the previously mapped areas in southwest and western Michigan at various phenological stages during the 1981 and 1982 growing season. Color, black/white IR and color infrared (CIR) transparencies (Kodak Aerochrome Infrared Film 2424 and 2443) were obtained using two ELM/500 Hasselblad camera systems fastened to a belly-mount of a Cessna Skyhawk. Imagery was acquired at approximately 305 m (AGL) using a 70 mm format with 80 mm lenses and Wratten 12 and 25 filters.

Low Level Imagery

Tower Photography

To assess whether infected plants could be detected at lower altitudes, a 35 mm camera was mounted from a 15 ft. hydraulic tower. Color, CIR and multispectral (70mm) film was taken of adjacent known diseases and healthy plants in the field. Vertical and angled photographs were taken at various exposure settings during full bloom, petal fall, fruit set and during senescence in 1981. Color and CIR negatives were analyzed with a color densitometer to detect density differences between plants at various wavelengths.

Spectral Signature

Changes in the mesophyll layer of the leaf, the primary site of infrared reflectance, may alter the spectral signature of an infected plant. To detect small reflective differences between healthy and diseased plants, radiometric measurements were obtained during the 1982 growing season using a field-portable spectroradiometer. The Spectron SE 590 (Spectron Engineering Co., Denver, CO) measures reflectance simultaneously at 256 wavelengths (400-1100nm), storing it on digital tape. Readings were recorded from 2.5 m above the plant canopy, using a 10 degree field of view. Black/White IR photographs (35 mm, Wratten 12 filter) were taken either before or after the spectral scan. Spectral reflectance ratios were obtained by normalizing readings to a $BaSO_4$ standard reflectance panel.

RESULTS AND DISCUSSION

Aerial photographs obtained during the 1981 growing season exhibited subtle changes in reflectivities from bush to bush. Although these changes were apparent throughout the growing season, they may represent differences in growth stages within and among bushes. Color differences were more obvious on color film than CIR. Analysis of the color and black/white IR photographs taken during the 1982 season is in progress and may prove to be a more sensitive technique.

Color and CIR photographs taken 2 m above diseased and healthy grapevines suggest reflectance differences may occur early in the growing season. Densitometric readings of photographs of blueberry bushes demonstrated larger reflective differences early (June) in the season for color film and mid-season for CIR film (Figs. 2 and 3).

Generally, diseased bushes exhibited decreased reflectance than healthy in all wavelengths, especially the infrared region.

Figure 1.

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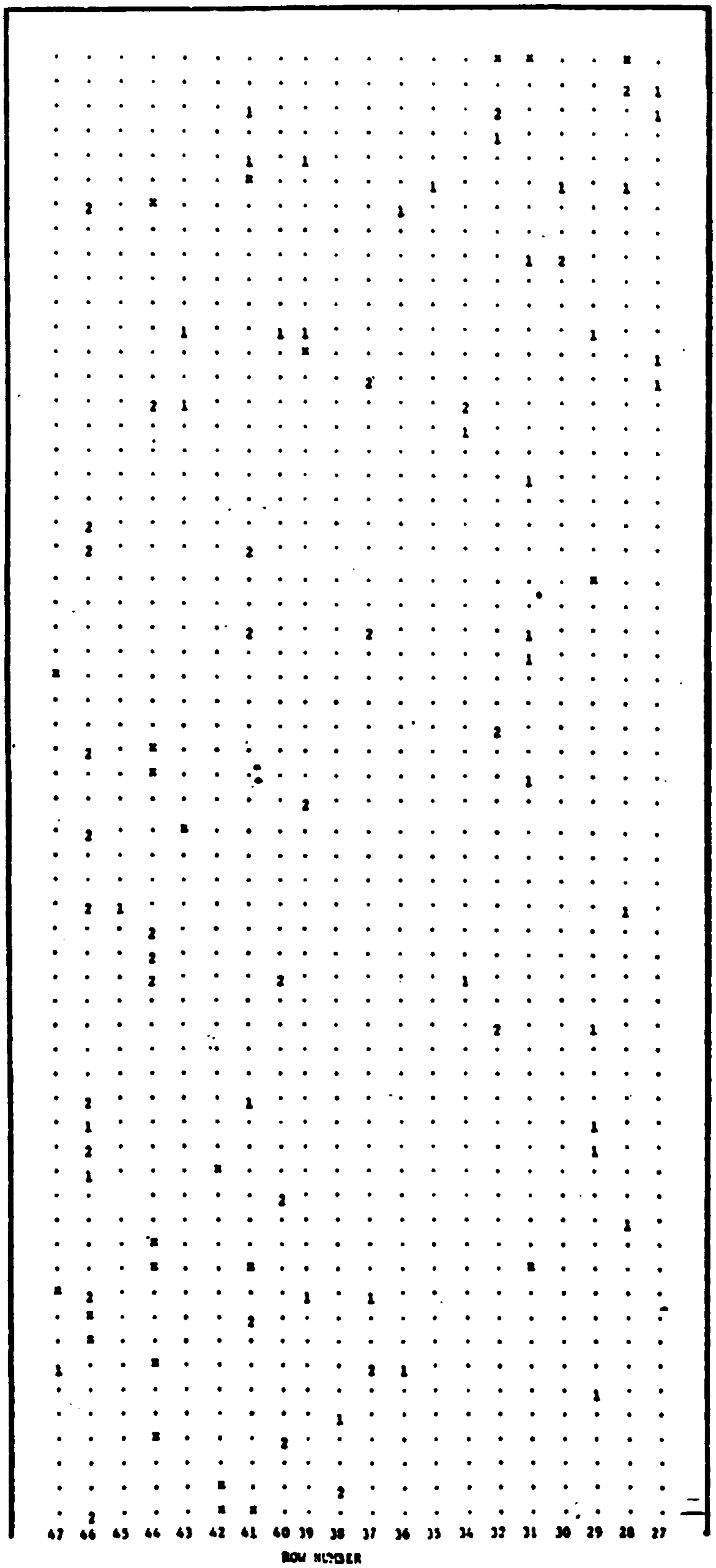

Diagram of ELISA indexed Jersey Blueberry plants over a two yr. period to determine the spread of blueberry shoestring virus(BBSSV); • = healthy, x = missing, 1,2 = indexed positive for BBSSV in 1981 and 1982 respectively.

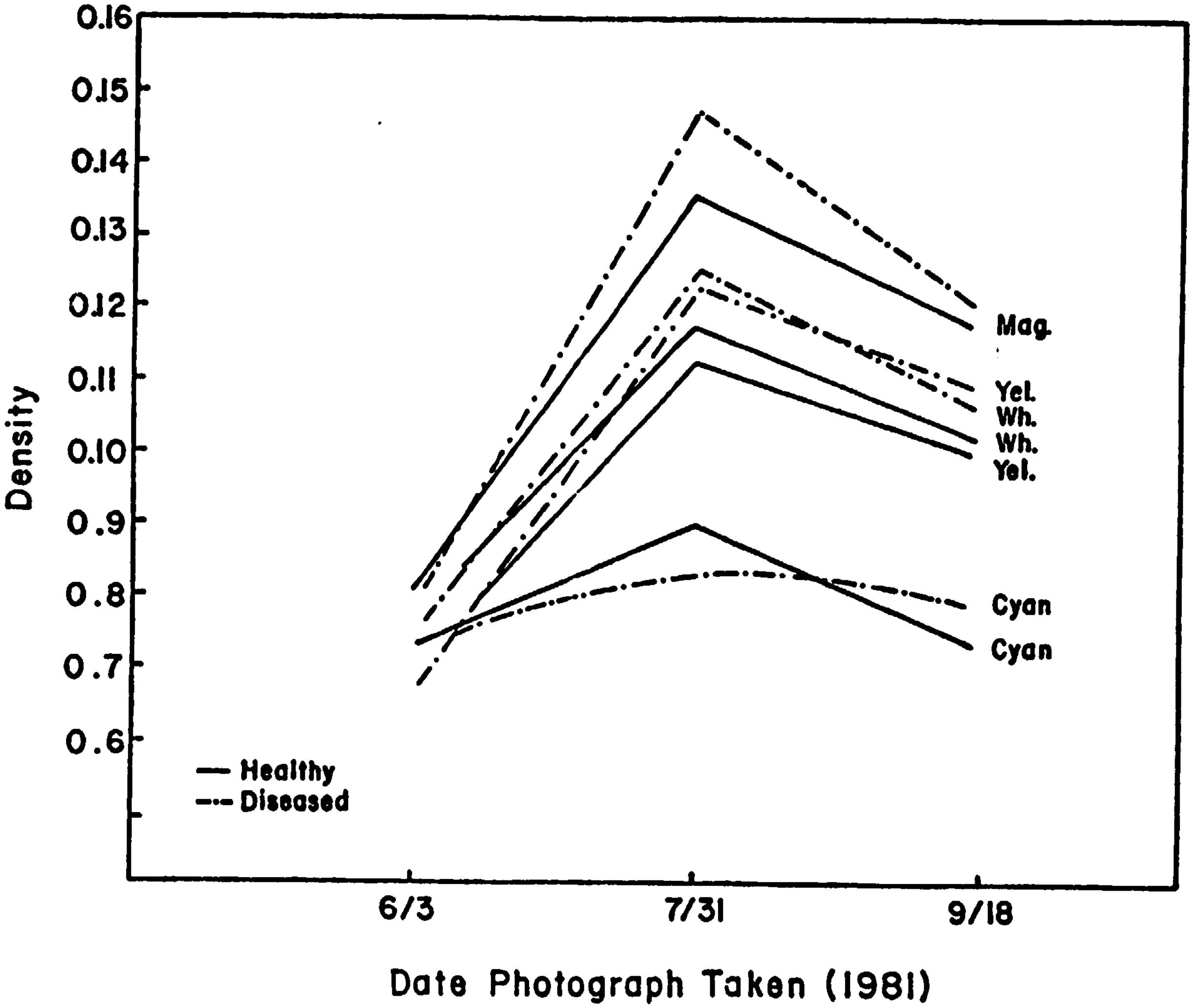
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.9
0.8
0.7
0.6
Density
Mag.
Yel.
Wh.
Wh.
Yel.
Cyan
Cyan
— Healthy
—·— Diseased
6/3
7/31
9/18
Date Photograph Taken (1981)

FIGURE 2

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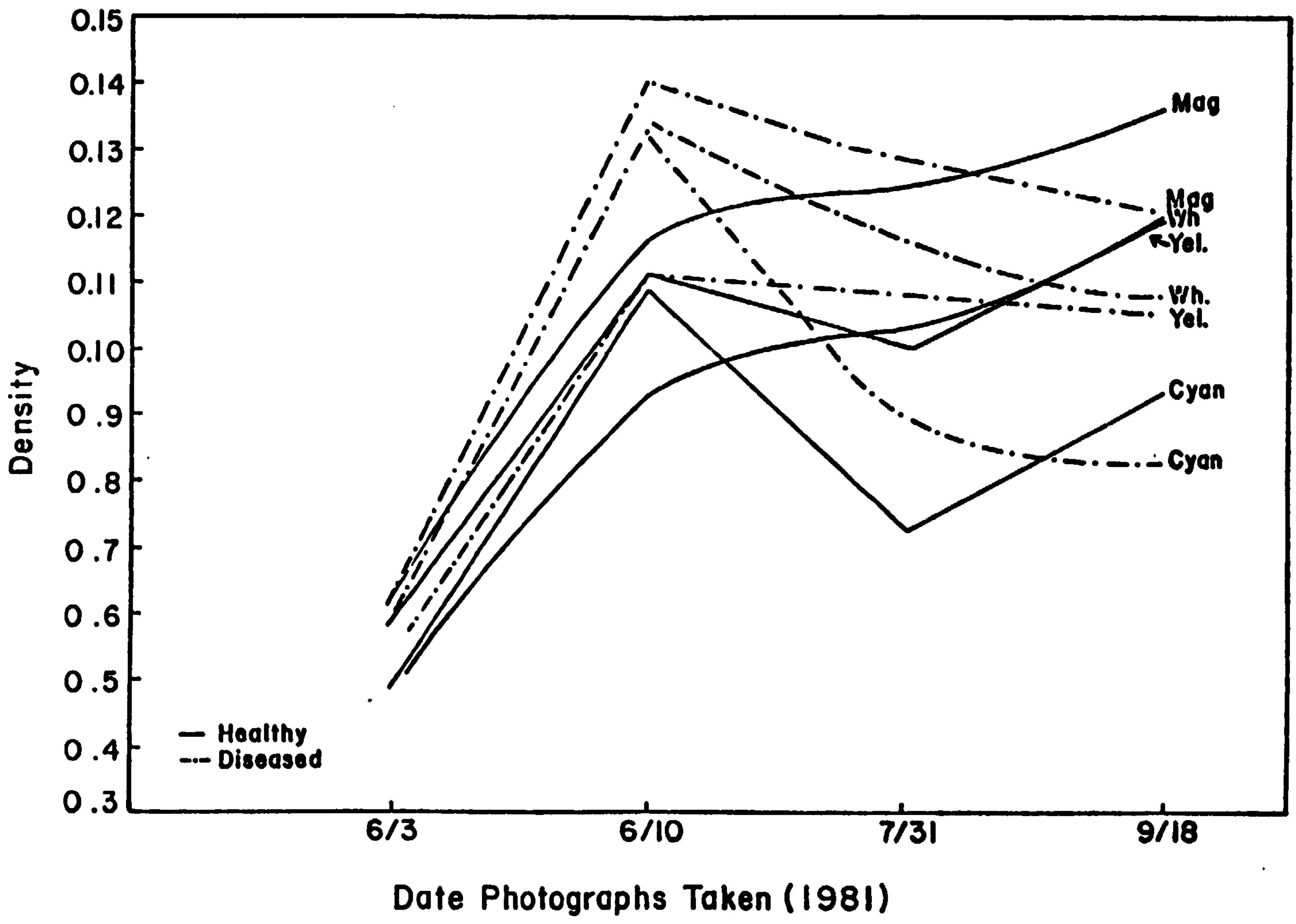
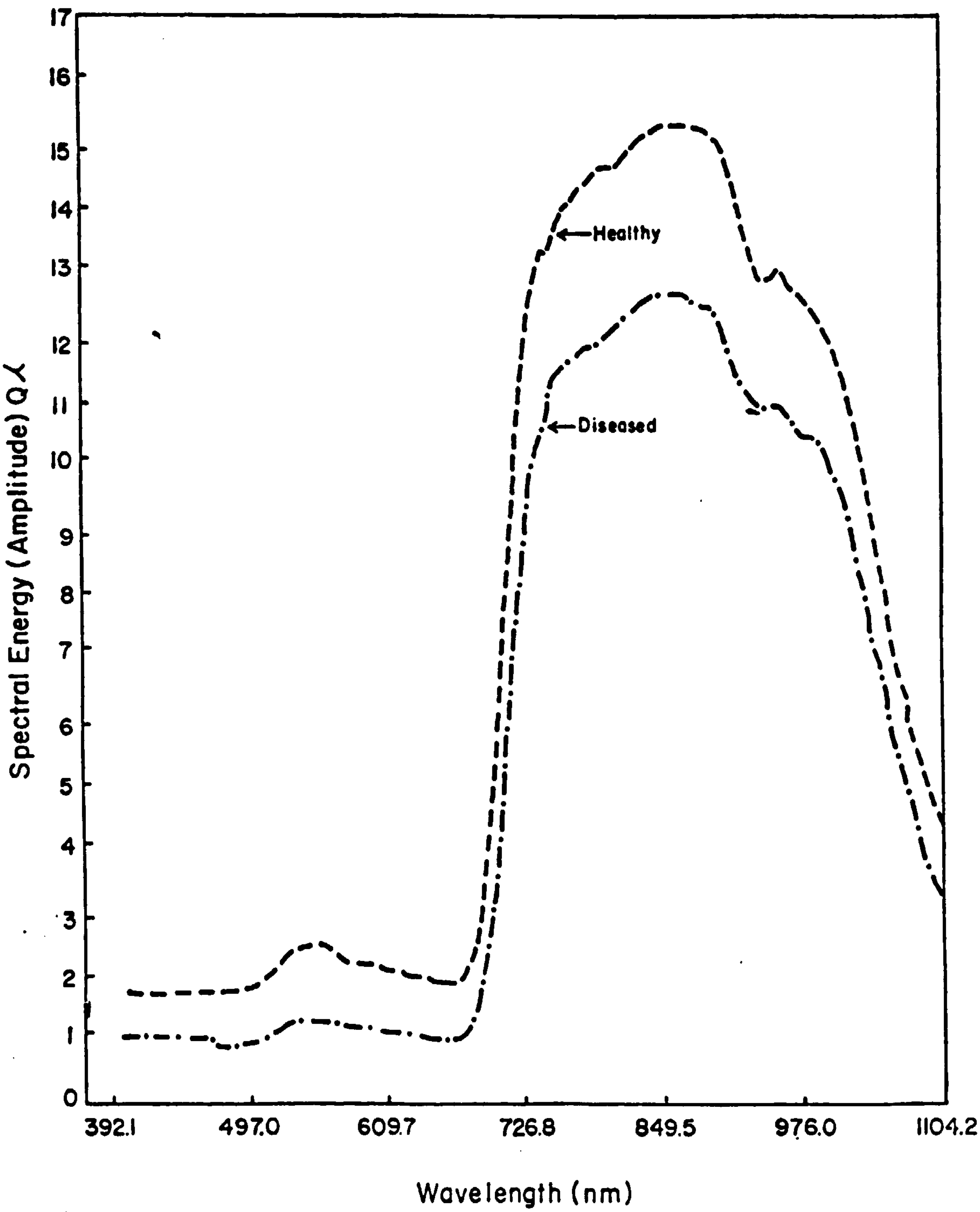


FIGURE 3

FIGURE 4

FIELD REFLECTIVITIES OF BBSSV-INFECTED AND HEALTHY CV. JERSEY HIGHBUSH BLUEBERRY BUSHES
COOPERSVILLE, MI - 1982



Spectrophotometric recordings were taken late in the 1982 growing season of 5 pairs of healthy and diseased plants in fields containing the three virus diseases; BBLMV, BBSSV and PRMV. In three of the five pairs observed, BBSSV infected blueberry bushes showed a lower reflectance in the infrared region (726.8-1007.7 nm) than their healthy counterparts (Fig. 4). One pair showed the reverse situation while the fifth pair showed no difference (Fig. 5). All grapevines infected with PRMV tested, exhibited decreased reflectance in the infrared wavelengths as compared to healthy. The reverse was observed for BBLMV infected blueberry bushes, where four of the five pairs showed increased reflectance over healthy. One pair showed no difference in reflectance.

The development of a reliable method for differentiating between diseased and healthy plants requires further field and laboratory analysis. Spectrophotometric analysis using the field portable unit obtained late in 1982, will be made during the entire season in 1983. Both aerial and low level detection will continue to be made using various techniques.

Objectives for 1983

1. Visual and densitometric analysis of aerial and low level photography.
2. Use of the field portable spectrophotometer at various phenological stages, to determine maximum differences between healthy and diseased plants at wavelengths ranging from 400 to 1100 nm.
3. Continued prediction of rate and pattern of spread of these diseases under field conditions.

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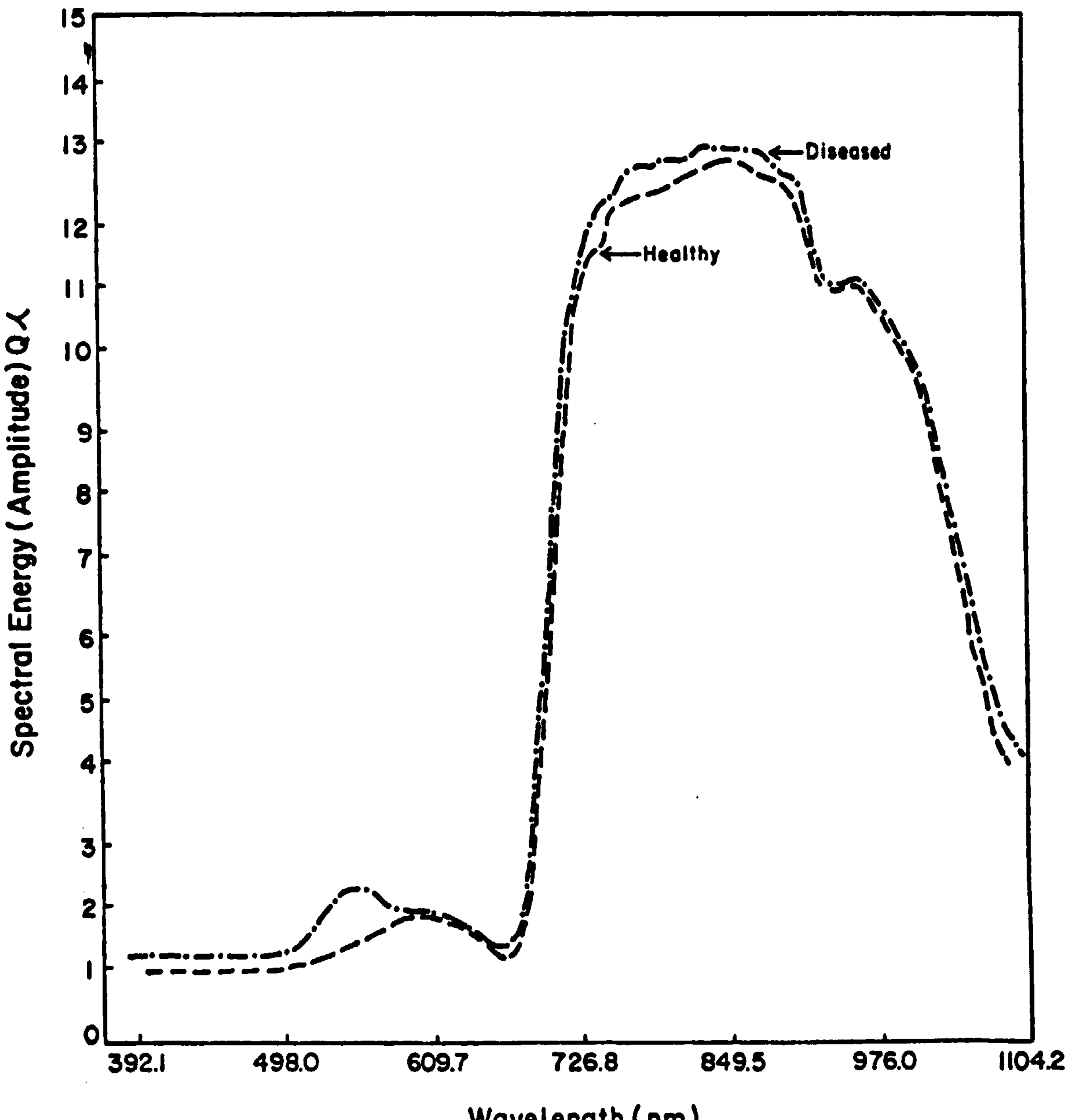
FIGURE 5

FIELD REFLECTIVITIES OF BBSSV-INFECTED AND HEALTHY CV. JERSEY HIGHBUSH BLUEBERRY BUSHES
COOPERSVILLE, MI - 1982



CONTRACTUAL ACTIVITIES

Important Farmlands Inventory

The Center for Remote Sensing is continuing work under contract with the Soil Conservation Service in preparation of Important Farmlands maps for counties in Michigan. The mapping involves the delineation of prime soil areas from soil survey information and the identification of unique farmland, water and urban built-up areas form aerial photography (U.S. Department of Agriculture, Secrètary's memorandum number 1827, revised, October 30, 1978). Unique farmlands are lands other than those designated prime that are used for the production of specific high-value food and fiber crops (e.g., tree and bush fruits, vineyards and vegetables).

The information is compiled onto a 1:50,000 base map of each county and area statistics per category are determined. The Important Farmland maps are being produced under the Land Inventory and Monitoring (LIM) program of the U.S. Department of Agriculture. Contracts for the preparation of Important Farmland maps of 11 additional counties were undertaken this reporting period, which brings the total under contract to 36 counties.

Changes in Aquatic Vegetation in Saginaw Bay

During the past decade, concern had been raised over the loss of wetland habitats along the shores of the Great Lakes, especially the cattail marshes which provide food and a cover habitat for waterfowl. Because coastal marshes are dynamic environments, changes in the amount and composition of aquatic vegetation may occur frequently in response to changes in water level, site moisture conditions, wave action from storms, water chemistry, sedimentation, human activities, and other processes. Fluctuations in the water level of the Great

Lakes are a major factor influencing marsh conditions, particularly vegetation growth and loss.

Center for Remote Sensing investigators studied coastal wetland changes and documented over time the types, distributions, and amounts of aquatic vegetation existing within three sites along the shoreline of Saginaw Bay in Lake Huron. This work was performed for the East Central Michigan Planning and Development Region.

The project mapped aquatic vegetation within three areas for selected years through interpretation of historical aerial photography. Vegetative area by category was determined per year and its change in subsequent years. The areas were chosen based on the availability of aerial photographic coverage, wetland location within Saginaw Bay, composition of aquatic vegetation, and other physical factors related to the nature of the marsh. The three areas selected are state wildlife areas of Quanicassee, Nayanquing Point and Wildfowl Bay.

Aquatic vegetation maps were prepared for Quanicassee and Nayanquing Point from aerial photography taken in 1950, 1969, 1975, and 1978; and for Wildfowl Bay from 1949, 1975, and 1978 photos. The selected years of photo coverage provide a record of marsh conditions during periods of medium to high lake levels.

A vegetation classification system and interpretation criteria were established. Through initial photo analysis, it was determined that four categories of aquatic vegetation could be identified on the aerial photographs: Submergents, cattails, mixed emergents, and sedges and grasses. Cattail areas were further classified into three stand density or cover classes (25%, 25-75%, and 75%), since cover is an important factor in the use of wetland habitats by wildlife.

Eleven aquatic vegetation maps were prepared and then digitized using an electronic digitizer. The resulting polygon files were converted to raster

(i.e., grid cell) arrays with a 0.1 acre cell size. These files were displayed on a color monitor for visual analysis and area statistics were calculated for each map category and listed on a printer.

The findings of the study indicated that between 1949 and 1978, Wildfowl Bay lost about 40% of its aquatic vegetation (2364 acres), about twice as much as either Quanicassee (21%) or Nayanquing Point (17%) lost. More importantly, Wildfowl Bay lost a greater percentage of its high/medium-density cattail stands (35%) compared to Quanicassee (31%) or Nayanquing Point (20%).

These greater losses may have been due in part to differences in wave-action protection, since both Quanicassee and Nayanquing Point are less exposed than Wildfowl Bay. The location of Wildfowl Bay on the eastern side of Saginaw Bay subjects it to enhanced wave-action and on-shore lake ice movement under the influence of the prevailing westerly winds. Other factors such as sedimentation or water quality differences may also have been involved.

A report entitled, "Changes in Aquatic Vegetation in Quanicassee, Nayanquing Point, and Wildfowl Bay," was prepared by Bill Enslin and Dwayne McIntosh for the East Central Michigan Planning and Development Region.

Digitized Soil Association Map of Michigan

A soils database for the entire state of Michigan was compleated this reporting period. The database was prepared for Dr. Maurice L. Vitosh of the Department of Crop and Soil Science, Michigan State University. The base map used was the Soil Association Map of Michigan, which was compiled by the Cooperative Extension Service and the Agricultural Experiment Station of Michigan State University and the Soil Conservation Service, United States Department of Agriculture. The map base was approximately at a 1 to 1,004,000 scale and contained 78 different soil associations. The database resulting from this map

contains 633 columns by 733 rows of grid cells. The size of one grid cell is one kilometer. A second variable, county boundaries, was also digitized in addition to the soil variable.

This database was then used by Dr. Vitosh and the Center to evaluate the spatial distribution of the effectiveness of soil nitrification inhibitors. The first step was to group the soil types into five suitability ratings with 1 being a poor response and 5 being a good response to nitrification inhibitors. This was done for the following time periods: early fall, late fall, early spring, late spring and siddress. Area totals and percentages were then generated for these groupings, both on a county and state level basis. Areas of high potential were then windowed out of the statewide file and photographed from the color monitor. The resulting color enlargements gave good visual documentation to supplement the generated statistics. The area totals and color enlargements were then used by a local chemical company to evaluate the effectiveness and market potential of a nitrification inhibitor they were in the process of developing and marketing.

Aerial Photography Support for Hybrid-Poplar Research

The Center for Remote Sensing acquired aerial photography of hybrid-poplar research stands for Packaging Corporation of America, Manistee, Michigan. The photographs were evaluated as part of a larger research effort of the company to access woody biomass production on a commercial scale. The objectives of this research are to identify short-rotation intensive hardwood silviculture productivity rates from already established large-scale hybrid poplar plantings; identify major plantation pests, diseases and their impacts and control measures needed to insure high biomass productivity in a large-scale operation; evaluate the need for weed control in the second growing season; determine the effect of

several herbicides used for post-planting weed control and their effect on tree growth in the field; test planting stock and site modification techniques which might increase initial establishment success leading to increased growth and survival and present a consolidated economic evaluation of large-scale biomass plantations. Light aircraft, 70mm aerial photographs (both color and color-infrared) were acquired at four time intervals during the summer of 1982. These photographs were provided to the various investigators (from Packaging Corporation of America, Michigan State University, U.S. Forest Service, Iowa State University and Michigan Technological University) for use and evaluation in their respective research endeavors. Additionally, Center staff have provided limited technical support in the incorporation of the aerial data into the ongoing research efforts.

CRIES Project Assistance

The Center for Remote Sensing assisted in creating a database of Jamaica. The database was completed last September and was created in conjunction with the Comprehensive Resource Inventory and Evaluation System (CRIES) project, Department of Resource Development, Michigan State University. The database contained three variables: 13 political divisions (parishes), 23 land use types and 240 soil types. The map base was at a 1 to 50,000 scale. The final database resulting from these maps contained 1220 columns by 480 rows of grid cells. The size of one grid cell was 4 hectares (200 x 200 meters). The database was initially created at a much finer resolution (.25 hectares per grid cell) in order to capture all of the important information from the base maps. This higher resolution data was then aggregated into the final database resolution of 4 hectares per grid cell so that a more general analysis could be done. The high resolution file was retained for future analysis.

This aggregated database was analyzed using various techniques. Overlays were run to find information on coffee and banana production potential. Many different types of area totals were also generated. After the analysis had been completed, the database was transfered from our microcomputer to the university's mainframe computer. There it was reformated and written out to tape in a format compatible with the geographic information system on the mainframe computer resident in Jamaica.

Projects similar to the Jamaica project are in the process of being completed for the countries of Kenya and Honduras. In addition to the analysis mentioned above, a powerful crosstabulation program has been written for CRIES by the Center to further analyze the databases of these new projects.

EDUCATION AND TRAINING

Interpretation of Color Infrared Airphotos for Forest Resource Inventories

October 28-30, 1980	Escabana, Michigan
June 16-18, 1981	Escabana, Michigan
September 22-24, 1981	Sault Ste. Marie, Michigan
September 27-30, 1982	Grayling, Michigan

This three-day shortcourse introduced its participants to the application of medium-scale (1:24,000) color infrared aerial photography to forest cover type mapping. In addition to lectures, ample time was allotted for discussion, demonstrations and practical exercises. A half-day session was devoted to field verification of the interpretation exercise.

Staff Members William D. Hudson and David P. Lusch were the instructors.

Aerial Photography for Natural Resource Management

March 29 - April 7, 1982
Kingston, Jamaica

Dr. David P. Lusch, Center for Remote Sensing, was one of three instructors for an 8-day workshop held at the University of the West Indies. Sponsored by U.S.A.I.D. in cooperation with Michigan State University, Comprehensive Resource Inventory and Evaluation System (CRIES) Project, this training activity acquainted the participants with the practical use of aerial photography for natural resource management. Fourty hours of classroom instruction (lectures and exercises) were supplemented with one day of field work dealing with ground-truth collection and interpretation verification. A 217 page study guide was prepared which included a set of specially prepared stereograms illustrating

the major land cover/use categories encountered in Jamaica.

Remote Sensing for Land Use Analysis

Geography 411 or Urban Planning 800, 4 credit hours
August 2-6, 1982

Three staff members from the Center for Remote Sensing, W.R. Enslin, W.D. Hudson and D.P. Lusch, conducted this 5-day, 4-credit course which emphasized the use of remotely sensed data to inventory land cover/use. Thirty-six hours of classroom instruction, including numerous exercises, were supplemented with 4 hours of field work collecting ground-truth information. As part of the course materials prepared for this class, the instructors wrote the Photo Interpretation Key To Michigan Land Cover/Use. Thirty-six students attended this course.

Land Use Mapping From Aerial Photography

August 10-12, 1982

This 3-day shortcourse was sponsored by the Center for Remote Sensing, in cooperation with the Departments of Geography, Urban Planning and Forestry, the Agricultural Experiment Station and the Cooperative Extension Service at Michigan State University, as well as the Michigan Resource Inventory Program, Department of Natural Resources. Emphasis was placed on the practical application of airphoto interpretation for land cover/use inventories with special reference to 1:24,000 CIR imagery and the Michigan Current Use Inventory. The twenty participants included representatives from the following agencies or firms:

Planning Commissions	10
Consulting Agencies	3
Utilities	2
State Government	2
Soil Conservation Service	1
Miscellaneous	2

Staff members William R. Enslin, William D. Hudson and David P. Lusch were the instructors.

Michigan State Remote Sensing Newsletter

The Center produces a quarterly newsletter (the first edition was March 1981) which is distributed principally in-state. The purpose of the newsletter is to keep state, regional and local decision-makers informed about new remote sensing capabilities and applications and to reach new potential users.

SPECTRUM

SPECTRUM is intended to keep Center investigators and others interested in remote sensing and its applications up-to-date on current news in the field. In SPECTRUM we attempt to brief readers on such things as recent developments in the field (principally excerpts from newsletters), upcoming meetings, workshops and seminars; staff travel; planned flights, etc. SPECTRUM is not released on a planned schedule--only as it is timely.

PUBLICATIONS

of the Michigan State University, Center for Remote Sensing

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1. Applicability of Satellite Freeze Forecasting and Cold Climate Mapping to the Other Parts of the United States. Center for Remote Sensing and Department of Entomology, Michigan State University, November 1981. 54p.

2. "Automatic Digital Image Registration." A. Goshtasby, A.K. Jain and W.R. Enslin. Proceedings 8th International Symposium on Machine Processing of Remotely Sensed Data, pp. 347-352. Purdue University, West Lafayette, Indiana, June 1982.

3. Interpretation of Color Infrared Airphotos for Forest Resource Inventories. William D. Hudson and David P. Lusch. Center for Remote Sensing, Michigan State University. July 1982. 55p.

4. Photo Interpretation Key to Michigan Land Cover/Use. William R. Enslin, William D. Hudson and David P. Lusch. Center for Remote Sensing, Michigan State University. August 1982. 71p.

5. "Assessment of Modified Surface Temperatures and Solar Reflectance Using Meteorological Satellite and Aircraft Data." J. Bartholic, S. Gage, A. Goshtasby, C. Mason. Presented at the Symposium on Study of Land Transformation Processes from Space and Ground Observations, Ottawa, Canada, August 1982.

6. Changes in Aquatic Vegetation in Quanicassee, Nayanquing Point and Wildfowl Bay. Prepared for the East Central Michigan Planning and Development Region. Bill Enslin and Dwayne McIntosh. Center for Remote Sensing, Michigan State University. October 1982.

7. "An Evaluation of Digital Landsat Classification Procedures for Land Use Inventory in Michigan." Richard Hill-Rowley. Ph.D. dissertation, Michigan State University, 1982. 258p.

8. Visual Interpretation of Landsat Imagery for the Identification of Coniferous Forest Types in Michigan. Kathryn L. Franklin, William D. Hudson, Carl W. Ramm, Center for Remote Sensing and Department of Forestry, Michigan State University. Submitted for publication to Michigan State University Agricultural Experiment Station. January 1983.

9. A Methodology for Constructing Vegetation/Physiographic Profiles Using Remote Sensing and Collateral Materials. William D. Hudson. Center for Remote Sensing, Michigan State University. In preparation.

10. Identifying Forest Types and Tree Species from Color Infrared Aerial Photographs. William D. Hudson. Center for Remote Sensing, Michigan State University. In preparation.

ASSESSMENT OF MODIFIED SURFACE TEMPERATURES AND SOLAR REFLECTANCE USING METEOROLOGICAL SATELLITE AND AIRCRAFT DATA

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ABSTRACT

Changes in surface temperature resulting from the activities of man are evaluated using meteorological satellite (NOAA and HCMM) and aircraft data. Study sites were located in Florida and Michigan. Thermal data showed that day surface temperatures over large areas could be increased by 10–15°C by modifications resulting from agricultural practices. Changes in reflected solar radiation as a function of agricultural practices were detectable using HCMM data. 1/

INTRODUCTION

Through time, man is gradually modifying more of the earth's surface to optimize conditions for habitation. The changes are largely for crop production, animal grazing and utilization of biomass for cooking and heat. In this process forests are being converted to pastures and farmlands, grasslands are being grazed by domestic animals, new species of plants are being introduced and major portions of the surface are being drained or irrigated.

This process has evolved slowly over centuries, but has speeded up dramatically during this century. Increasing modification of the surface for food production has been an essential part of increasing the earth's carrying capacity from two billion at the turn of the century to over four billion at the present time. Further, these changes will be occurring at an increasingly rapid rate as the projected population of the earth doubles by the year 2020 [1].

Relatively few studies have assessed the magnitude of these changes or their impact on surface boundary conditions [2,4]. Many characteristics of the surface, including temperature, radiation and surface roughness, could be altered significantly. This paper shows that information available from the National Oceanic and Atmospheric Administration (NOAA) and NASA's Heat Capacity Mapping Mission (HCMM) satellites and airplane scanner data can help assess the impacts on surface temperature and radiation of man's modification of our planet.

METHODOLOGY

Several recently launched meteorological satellites have collected valuable data on reflected radiation in the .5 to 1.1 micron range. This band has the information needed for good estimates of solar reflectance from different surfaces [5]. Also, data from scanners sensing in the 10.5 to 12.5 micron range are available on several satellites which can be used to determine surface temperature. Accuracy and resolution of these systems is sufficient to characterize vegetative types and to provide answers about the magnitude of changes that might be expected with deforestation or other significant changes in existing vegetation.

NOAA satellite data provides one kilometer resolution in the thermal (10.5 to 12.5 microns). The satellite orbits over at approximately 1000 and 2200. The sun-synchronous HCMM satellite provides high resolution thermal data with a .6 km by .6 km resolution at nadir, in the 10.5 to 12.5 micron range. Also, the concurrent visible channel 0.5 to 1.1 microns with a dynamic range of approximately 100 percent albedo and resolution of .5 km by .5 km at nadir potentially will provide the essential data required to meet the objective of characterizing solar reflectance [6].

For the NOAA data, transparencies were used, digitized and analyzed on the Image 100 at the Kennedy Space Center. The HCMM data was obtained in both pictorial and digital forms. Ana-

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1/Michigan Agricultural Experiment Station Journal Article Number 10531.

lysis was done at the Center for Remote Sensing and the Image Processing Laboratory at Michigan State University.

The digital HCMM reflected radiation data were used to find the relation between vegetation types and reflected values. The reflectance image was thresholded at different values and the regions showing the same reflectivity were isolated for each classification. The isolated regions were compared with an already classified Landsat image.

A Daedalus DS-1250 scanner with 8-14 microns thermal channel was flown to obtain high resolution inputs required to assist in the analysis. This data was acquired on analog tape then digitized and analyzed on the Image 100 at the Kennedy Space Center.

The study areas were mainly in Florida and Michigan. The NOAA satellite and aircraft data were obtained for Florida and HCMM data was used for analysis of the Michigan test site.

RESULTS

NOAA thermal satellite imagery for April 28, 1978 at about 1000 (Fig. 1) shows darker areas as warmer and lighter areas as cooler. The agricultural areas in the Mississippi Valley and the southern portions of the United States including Georgia, Alabama and South Carolina, plus major areas of Florida, are shown to be markedly warmer (darker) than the adjacent naturally vegetated areas. Separate analysis indicates that many of the darker areas are about 10-12°C warmer than the adjacent natural areas.

More detailed examination of the Florida peninsula is possible in Fig. 2 (note that warmer areas appear lighter, the reverse of Fig. 1). In April, many fields in north central Florida are tilled and crops do not yet cover a significant portion of the surface. These agricultural areas are in long, broad strips generally lying in a north-south direction and are much warmer. Some of the greatest thermal contrasts in southern Florida occur between the water conservation reserves in the Everglades and the adjacent agricultural areas that have been drained. The adjacent agricultural areas are to the north and just south of Lake Okeechobee. Both drainage and agricultural practices are affecting the surface conditions, causing temperatures to be significantly warmer than natural areas.

Image displays of aircraft thermal scanner data are shown in Figures 3A and 3B. Two dissimilar areas were chosen for study in the Taylor Creek watershed located north of Lake Okeechobee, Florida. The first area, shown in Fig. 3A, was primarily improved grass pastures used for grazing dairy cattle. The second area (Fig. 3B) includes pasture, marsh and a large citrus grove. The thermal data of Fig. 3A were obtained at 1222-1225 EST on April 28, 1978. Windspeed was 700 cm/sec, air temperature was 26.1°C and the relative humidity was 59 percent (dew point 11.1°C). Thermal data of Fig. 3B were obtained at 1432-1435 EST on April 26, 1978 and meteorological conditions were similar to those measured on April 28. These surface meteorological measurements were made at a height of 10m. A uniform general rain of about 3cm had fallen on the area two days prior to the flights. Soil moisture conditions were good for growth [3].

U.S. Highway 441 runs N-S through the image in Fig. 3A. To the east of the highway the effects of high dairy cattle population density are easily seen. In the irregularly-shaped areas heavy cattle traffic had eliminated plants. A mixture of sand and partially decomposed manure made up the surface cover. The surface temperatures in this area were greater than 42°C. Similarly, Field 1, which had apparently been cut for hay and then grazed heavily prior to April 28, showed little spring growth and temperatures were in excess of 42°C. Field 2 of the same species, primarily Pangola (Digitavia decumbeus) had been cut for hay but had not been grazed. It was in a healthy growing condition and ranged from 36-42°C. Field 3 was rather heterogeneous, containing patches of grass interspersed with broadleaved weeds and thinner stands of grass and ranged in temperature from 28-36°C. Evapotranspiration (ET) and heat flux values for Field 1 were 20 and 30 mw/cm^2, respectively, and for Field 3 with higher ET were 40 and 10 mw/cm^2 [3]. Wet areas with woody shrubs as the primary gound cover had the coolest temperatures in the scene with a range of 22-26°C.

In Fig. 3B the marsh vegetation was coolest (about 21-24°C) and the citrus ranged from 24-28°C. Pasture 1 was poorly managed and had temperatures from 31-38°C while Pasture 2 was not over-grazed and ranged in temperature from 24-31°C.

Fig. 4A shows the HCMM thermal infrared data over the northern lower peninsula of Michigan. This imagery is from September 26, 1979. Digital values showed that the agricultural areas were warmest when compared to other areas. Surface radiant temperature for agricultural areas average 20°C while the average radiant temperature for water was 8°C. The surface temperatures for other surface types fall between these two values. Average temperatures of surface types acquired from this scene are shown in Table 1. The distinct differences in temperatures between the surface types shows the relationship of surface temperature and surface types.

TABLE 1 Average Temperature for Different Surface Types as Obtained from HCMM Data on September 26, 1979 for the Northern Portion of the Lower Peninsula of Michigan

Surface Type	Average Temperature
Water	8°C
Swamp	15°C
Forest	17°C
Agricultural Areas	20°C

Fig. 4B is the HCMM reflectance image of the same scene. Again, digital values showed the dependency of reflectance to the surface types. Experiments showed that it is even possible to verify some vegetation types solely by their reflectance values. In Fig. 4B reflectance values between .07 and .08 are isolated in black, which show the coniferous areas very well (see the areas pointed to by the arrows). This was verified by referencing the Landsat classified image of August 1, 1975 [7], Fig. 4C. This shows that the HCMM satellite reflectance data can be used to characterize this earth surface parameter.

DISCUSSION

From the analysis of the satellite data, it is clear that man's activities have significantly altered massive portions of the earth's surface. These changes have, in turn, modified the planet's boundary temperatures. The change is not only large in area, but also in magnitude. Frequently 10-12°C warmer temperatures were found in agricultural areas when compared to the natural surface (Fig. 3 and 4). These modifications could significantly impact the thermal radiation leaving the earth's surface and the repartitioning of energy into sensible and latent fluxes.

Further, the aircraft thermal data vividly show (Fig. 3A and 3B) that even within the agricultural areas, as vegetation types are changed or overgrazing occurs, there can be further significant changes in the thermal regimes. These scenes showed overgrazed areas were greater than 42°C while well-watered nondormant pastures were approximately 30°C. For these temperature differences to occur, major differences in energy going into evapotranspiration must exist. Thus, the fluxes of vapor and heat are considerably different depending on how the surface is managed. These surface differences will ultimately impact the hydrological balance.

The impacts of these changes over the composite area of the Florida peninsula could potentially have significant impacts on local weather. Some evidence of this modification is visible in Fig. 5. Lake Okeechobee, which is a man-made lake, is shown to be modifying the cloud pattern over the southern portion of the Florida peninsula in this figure.

Modifications in a more temperate area are clearly shown by the example using HCMM data for the peninsula of Michigan. This analysis also showed that significant changes in reflectance could occur with changes in vegetation. Modifications in this reflectant component could have long term ecological implications since solar radiation is the main driving force for temperature increase, hydrological changes and biological processes.

CONCLUSION

Modifications of surface temperature and radiation were clearly observable from analysis of satellite data. Both the spatial distribution and magnitude of these changes can potentially be monitored using satellite data. Thus, some preliminary considerations for the habitability of areas of the earth can start to be developed. Of greatest concern, however, is that the population is expected to increase by an additional 50% by the turn of the century, so the process of change examined in this paper can be expected to accelerate in the years ahead.

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A

B

Fig. 3 Images of aircraft thermal scanner data.

1=Field 1 3=Field 3
2=Field 2 4=Over Grazed
5=Barn

1=Pasture 1 3=Marsh
2=Pasture 2 4=Citrus

Fig. 4A Fig. 4B Fig. 4C

Fig. 4A HCMM Day-IR image of 26 Sept '79, Scene ID: A-A0518-18110-2.

Fig. 4B HCMM Day-Visible image of 26 Sept '79, Scene ID: A-A0518-18110-1.

Fig. 4C Classified Landsat data of 1 August '75 (2191-15453 and 2191-15460).

Fig. 5 A photograph from space looking south over the Florida peninsula.

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Fig. 1 Thermal scene for the eastern United States from NOAA satellite for 28 April '78 at about 1000.

Fig. 2 An expanded view of Fig. 1 showing mainly Florida.

AUTOMATIC DIGITAL IMAGE REGISTRATION

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ABSTRACT

This paper introduces a general procedure for automatic registration of two images which may have translational, rotational, and scaling differences. This procedure involves 1) segmentation of the images, 2) isolation of dominant objects from the images, 3) determination of corresponding objects in the two images, and 4) estimation of transformation parameters using the center of gravities of objects as control points. An example is given which uses this technique to register two images which have translational, rotational, and scaling differences.

I. INTRODUCTION

Given two images of the same scene in coordinate spaces (x,y) and (x',y'), image registration is the determination of transformation functions f1 and f2 such that given the coordinates of a point in one of the images, we can compute the coordinates of the same point in the other image by

$$x = f1(x',y')$$
$$y = f2(x',y').$$

The parameters of transformation functions f1 and f2 are estimated using a set of corresponding control points from the two images. Selection of control points by hand is often time consuming and is susceptible to systematic errors. It is desirable to make the control point selection process automatic so that the whole registration process can be carried out automatically.

An automatic technique for selection of control points in the first image is available[4,11]. This involves selection of windows which 1) contain a large number of high gradient edges, 2) contain a large number of connected edges, 3) are unique with respect to neighboring windows, and 4) are well dispersed in the image. The upper left hand corner of the window satisfying these properties is taken as a control point. In the second image, the control points are obtained by carrying out a search for the position of best match for each window from the first image[3,7] using either the sequential similarity detection algorithm[1] or the cross-correlation technique[2].

Selection of control points automatically in this manner has shown to be satisfactory as long as the two images have only translational differences. For images with rotational, and scaling differences, the search process becomes inaccurate and unreliable. In such situations, image points which are routinely used as control points include intersections of lines (intersections of roads in aerial or satellite images) and positions where lines join (like positions where rivers join).

In this paper we introduce a technique for automatically finding corresponding control points in two images which may have translational, rotational, and scaling differences. The technique uses *center of gravities of objects as control points*. Because the coordinates of the center of gravity of a shape is the average of the coordinates of the pixels on its boundary, if any error has been made in extracting the boundary, that error is averaged over the whole boundary and so the effect on the center of gravity is small. Another beneficial property of the center of gravity as control point is that its location can be determined upto subpixel accuracy while the traditional control points (like intersection of roads) can

take only discrete values. Our registration algorithm consists of following steps. 1) Segmentation of the images, 2) isolation of dominant objects from the images, 3) determination of corresponding objects in the two images, and 4) estimation of transformation parameters using the center of gravities of objects as control points.

II. IMAGE SEGMENTATION

There is no single image segmentation algorithm which can reliably segment an arbitrary image. Depending on the type of imagery, different techniques have been developed by different authors. Some of the techniques like the recursive region splitting technique[3], the semantic region growing technique[5], or the region classification technique[7] work especially good on multispectral aerial or satellite images.

For HCMM satellite images which are of interest to us, a simple segmentation technique based on gray level thresholding appears to give satisfactory results. A number of techniques have been proposed to obtain an appropriate value of the threshold. The threshold value can be selected by maximizing the global average contrast of the image[8]. In another method[10], the threshold value is determined by minimizing the sum of the squares of the differences of the original image and the thresholded image pixel by pixel. Katz[6] has determined the threshold value using the edge information present in the image. We have chosen the Katz algorithm for the segmentation of HCMM images because of its speed and performance on this type of image. The algorithm consists of the following four steps.

1. Compute the gradient of the original image, call it image G.
2. Find the high gradient pixels by thresholding image G. Replace all values above the threshold by 1 and all other values by 0. Call the new image H.
3. Multiply H by the original image, call the new image M. Note that M will contain only high gradient pixels of the original image.
4. Compute the average gray value of image M (nonzero pixels only). This will be the required threshold value.

Note that the algorithm requires a user-specified parameter in step 2.

III. FINDING CORRESPONDING REGIONS

Once the two images are segmented, we isolate regions with closed boundaries in each one of the images. A region which touches the boundary of the image is not isolated. Further, very small regions are discarded. The task is now to determine the correspondence between the two sets of regions.

Regions in the two images could be matched based on shape alone. A number of shape matching procedures are available in the literature. Fourier descriptors[12], and invariant moments[13] have been extensively used for shape matching. The distribution of chord lengths joining the center of gravities of regions to its boundary points has been proposed as a measure of shape[11].

Price and Reddy[14,15] extracted a number of features from each region including roundness (perimeter^2/4π area), length to width ratio, color, intensity, location, relative position to match the regions in the two images. Their matching technique seems to best fit our problem and we have used it with some modifications in the example given in section V.

IV. TRANSFORMATION FUNCTIONS

Selection of the right transformation function is another important factor in the registration of digital images. The best transformation function for registering two images which have only translational differences is very simple and has only two unknown parameters. Applying a transformation function with more parameters makes the registration process costly and probably less accurate. On the other hand, images of the same scene taken at different angles require a transformation function with 8 unknown parameters (the projective transformation) and a transformation function with less parameters cannot register them accurately.

Usually it is known (or assumed) that the two images have only specific differences and can be registered using an appropriate transformation function. There are cases though, where no a-priori information is available about the images and we have to select the best transformation function to register them. Using the control points, it is possible to find some knowledge about the images and then select the appropriate transformation function. For example,

1. Using two pairs of corresponding control points, it is possible to find two corresponding line segmentss in the two images. If the ratio of corresponding

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line segments is not equal to 1, it shows that the two images have scaling differences.

2. If the ratio of corresponding line segments are not the same for different line pairs, it shows that one of the images is geometrically distorted with respect to the other.
3. If the angle between corresponding line pairs in the two images are different, it shows that the images have not been obtained from the same angle.

The above information helps in the selection of the right transformation function.

To be able to estimate parameters of a transformation function with n unknowns we need at least n/2 corresponding control points (which are not colinear). Usually more control points are used and parameters are estimated by minimizing the mean-square error.

V. AN EXAMPLE

To show how the proposed technique works, we have taken a 240x240 subimage of the day-visible image obtained by the HCMM satellite on 26 September 1979 from an area over Michigan(scene id:A-A0518-18110-1). The digital image acquired by the satellite (figure 1) was used as the first image. The second image was the digitized image of the print of the same scene provided by the National Space Science Data Center. We arbitrarily digitized the print so that the second image is translated, rotated, and has scaling differences with respect to the first image, as shown in figure 2. The digitization was done using the Spatial Data Systems Vidicon in the Pattern Recognition & Image Processing Laboratory of the Computer Science Department, Michigan State University.

A. SEGMENTATION

The Katz technique[6] was used to segment the images. The gradient images were clipped at 98% of the gradient histogram area. Thus average intensity of the 2% of the highest-gradient pixels was used as the threshold value for segmenting the gray level images. We found that other day-visible images of HCMM can be segmented satisfactorily using the same parameter value (98%). Figures 3 and 4 contain the segmented images of figures 1 and 2, respectively.

B. CONTROL POINTS

Ten control points were used to register the two images. To obtain the control points, we have used a technique similar to the one proposed by Price and Reddy[15] to find corresponding regions in the two images.

Object size (perimeter) and shape (roundness=perimeter^2/ 4πarea) were used to find the two most similar object pairs in the two images. Let's call them P and Q. Now relative distance (distance of the center of gravity of an object to the center of gravity of P/distance between center of gravities of P and Q), and relative position (angle beteen the line connecting the center of gravity of an object to the center of gravity of P, and the line connecting the center of gravities of P and Q) are used to match the rest of the objects. Since we have two kinds of objects (bright objects in dark background and dark objects in bright background), the match is carried out only between objects of the same kind. Once the corresponding objects in the two images are determined, their boundaries are extracted (see figures 5 and 6), and their center of gravities are computed which are the control points.

C. TRANSFORMATION FUNCTIONS

The two images which we are registering have been derived from a single image by artificially introducing translational, rotational, and scale change. Therefore, one would suspect that the transformation of Cartesian coordinate systems would be able to bring the images into registration. Using the control points, we computed the ratio of corresponding line segments and found that the ratios change slightly when changing the line pairs. This shows that one of the images has small geometric distortion with respect to the other. Such distortion might be due to the digitizer lens or shrinking of the print's paper. The transformation function that can register images with geometric distortions is the polynomial mapping function. We used a second order polynomial mapping function given by,

$$x' = a0+a1x+a2y+a3xy+a4x^2+a5y^2$$

$$y' = b0+b1x+b2y+b3xy+b4x^2+b5y^2$$

Figure 7 shows a resampled image of figure 2 using the above polynomial mapping function with the nearest neighbor technique. We also used the transformation of Cartesian coordinate systems and the affine transformation. However, these transformation functions did not give satisfactory results.

The accuracy of the whole registration process to a large extent depends upon the accuracy of control points. In order to check the accuracy of the control points we segmented the images with different threshold values (from 90% to 99.5%) and computed the center of gravities of the objects for each threshold value. The maximum shift in the center of gravity was 0.7 pixels and the average shift was 0.4 pixels. Therefore, the center of gravities appear to be stable over a reasonable range of threshold values used in the segmentation process.

VI. CONCLUSION

An automatic technique for registration of images that may have translational, rotational, and scaling differences has been presented. This technique can also be applied to images with small shearing and geometric distortions (such that in the domain of an object the shearing and geometric distortions is negligible). Images with distortions due to earth rotation, earth curvature, and scanner nonlinearity can be registered using this technique.

More research is required to see the feasibility of this technique in registering images obtained by different satellites and/or different sensors.

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Figure 1. Digital image acquired by HCMM satellite.

Figure 2. Digitized image of the print.

Figure 3. Segmentation of image of figure 1.

Figure 4. Segmentation of image of figure 2.

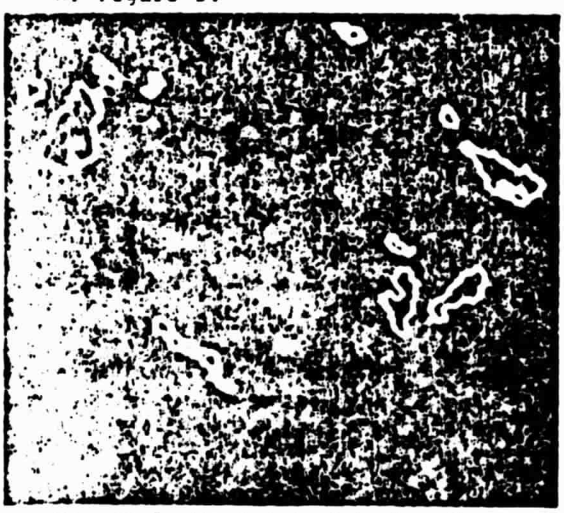

Figure 5. Dominant objects of image of figure 3.

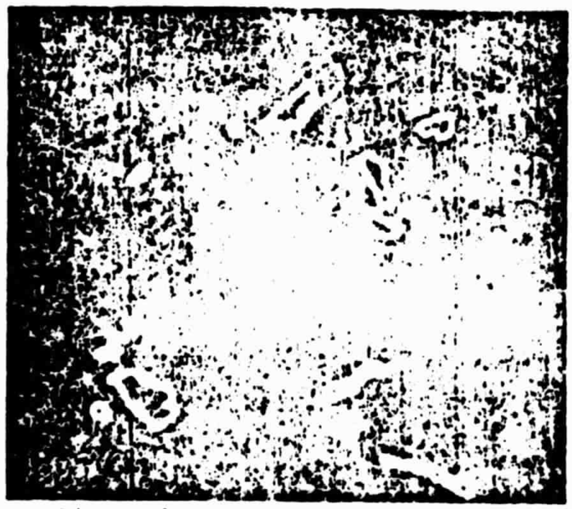

Figure 6. Dominant objects of image of figure 4.

Figure 7. Resampling of image of figure 2 to register with image of figure 1.

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